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Introduction

Intravascular ultrasound has been shown to be of significant value in the assessment of a variety of vascular disease processes (1). The technique does, however, require the invasive introduction of an ultrasonic transducer into the vessel itself. A non-invasive alternative would be highly desirable. This paper describes the use of a new, non-invasive procedure capable of rendering internal views of the pulmonary artery tree. It is based on the combination of "virtual reality" image processing with ultrafast, contrast-enhanced 3D magnetic resonance angiography.

Materials And Methods

The virtual pulmonary artery angioscope combines two technologies. The first is the acquisition of high quality pulmonary angiograms. The second is the segmentation and surface rendering software used to generate virtual endoscopic views of the interior vessel walls.

Vascular MR images were collected on a commercial 1.5T scanner equipped with fast gradients on all three axes (Signa Horizon EchoSpeed, GE Medical Systems, Milwaukee, Wisconsin). Using an optimized 3D spoiled gradient-echo sequence (3D SPGR) (G.C. McKinnon, unpublished data), 44 coronal sections covering the entire pulmonary artery system were acquired in 24 seconds. The speed of the acquisition allowed the data to be collected breathheld. Motion artifacts could thus be reduced, greatly adding to the sharpness of the anatomical structures. Sequence parameters were as follows: TE = 1.6 ms, TR = 3.4 ms, flip angle = 40°, 0.75 NEX, receiver bandwidth = ±62.5 kHz. A field of view of 32x32 cm coupled with a 192x192 matrix rendered an in-plane resolution of 1.7x1.7 mm. Employing a section thickness of 2 mm, the voxels were almost isovolumetric.

Vascular signal enhancement was obtained using the contrast-enhanced MR angiographic technique described by Prince, et al. (2). Scanning was initiated simultaneously with the start of bolus injection. The contrast bolus consisted of gadolinium-DTPA (Schering AG, Berlin, Germany), at a dose of 0.4 mmol/kg body weight, and was injected uniformly over 15-18 seconds into an antecubital vein via a 20 gauge peripheral intravenous catheter. Because of the extremely short TR and the large concentration of paramagnetic contrast agent, the pulmonary arteries are afforded extremely high contrast with the surrounding parenchyma, resulting in an arterial tree which is essentially white in a black background.

Post-processing of the vascular images was performed on an image processing workstation (Advantage Windows, GE Medical Systems, Buc, France) using a prototype software package (Advantage Navigator, GE Medical Systems, Buc, France). With this software, the vessels are segmented using an image intensity threshold, and the threshold boundary is treated as the interior vessel wall. The resulting interior space can be traversed with a virtual angioscopic camera by surface-rendering the interior walls using a 3-dimensional ray-casting technique. The field of view of the virtual camera, its position, and its orientation can be varied at will under operator control via a workstation mouse. Thus, the virtual angioscopic camera can be placed in the lumen of a vessel and the vessel viewed from the inside. Sequences of such views can be generated as the virtual camera is moved through the lumen. When viewed in cinematic fashion, a 'flight' through the lumen of the pulmonary arteries can be simulated.

To demonstrate the potential of this technique, virtual MR angioscopy was performed in the pulmonary arteries of a healthy volunteer and a patient with pulmonary embolism located in the left lower lobe pulmonary artery. The presence of the embolus had been documented with spiral CT.

Results And Discussion

With the virtual MR angioscope, the lumen of the pulmonary artery tree of the volunteer was probed beginning in the pulmonary trunk, diving into the right and left pulmonary arteries, and from there into the lower lobe arteries with their respective segmental and sub-segmental arteries. In both lungs, the arterial system was followed into the periphery of the lateral-basal segment, permitting a view of the lumen of sub-sub-segmental arteries. The smallest vessel traversed was under 3 mm in diameter.

Fig. 1A shows a maximum intensity projection (MIP) of the original data set, also showing the paths taken with the angioscope. Fig. 1B shows an angioscopic view into the right pulmonary artery, visualizing the origin of the three lobar arteries.

In the patient, virtual angioscopy was also performed starting at the pulmonary artery bifurcation. In this case, the target of the angioscopic tour was an embolus occluding the left lower lobe artery, which could be

clearly seen in the MIP of the original data (Fig. 2A). After traversing the left main pulmonary artery and diving into the lower lobe artery, the embolus came into view (Fig. 2B). An additional wall-adherent thrombus could be clearly delineated proximal to the occluding thrombus. This wall thrombus was not appreciated on the MIPs, but could be seen on reformatted axial sections.

One important issue relates to the time required to explore all possible branches of the pulmonary artery tree. The time for defining and calculating the angioscopic images of any particular 'flight path' ranged between 10 and 40 minutes, depending on the length of the path. Any clinically relevant use of this technique must thus target selected branches based on therapeutic relevance and difficulties in interpretation of conventional MIP and source images. Used in this fashion, virtual angioscopy has the potential to become a powerful new tool, enhancing the diagnostic performance of 3D MR angiography in the assessment of pulmonary embolism.

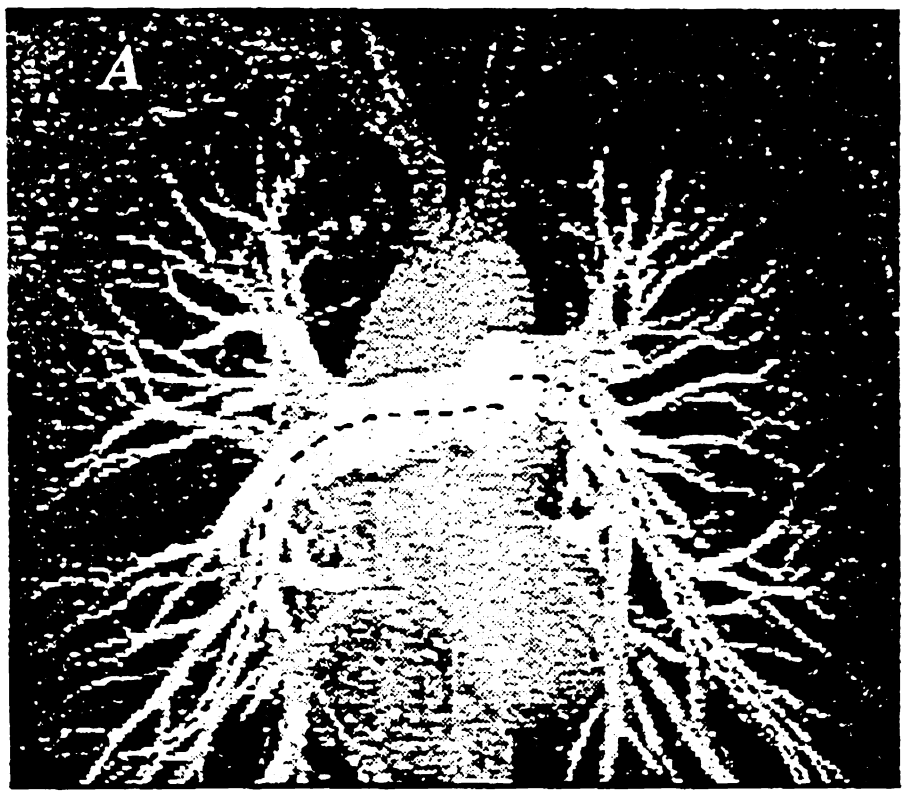

Fig. 1. Healthy volunteer.

A Maximum intensity projection of the pulmonary arteries showing the paths of the virtual angioscope.
B An angioscopic view of the origin of the three right lobar arteries.

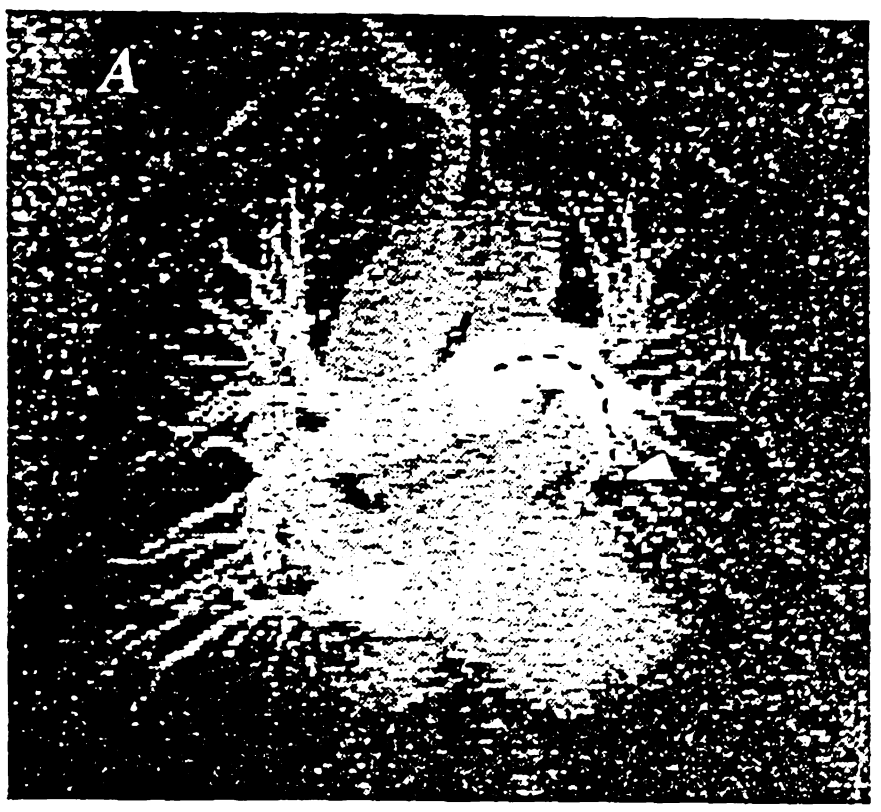

Fig. 2. Patient with pulmonary embolism.
A Maximum intensity projection of the pulmonary arteries showing the path of the virtual angioscope and the embolus occluding the left lower lobe artery (arrow).
B An angioscopic view of the occluding embolus (double arrow). Additional wall thrombus is apparent (single arrow).

References

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